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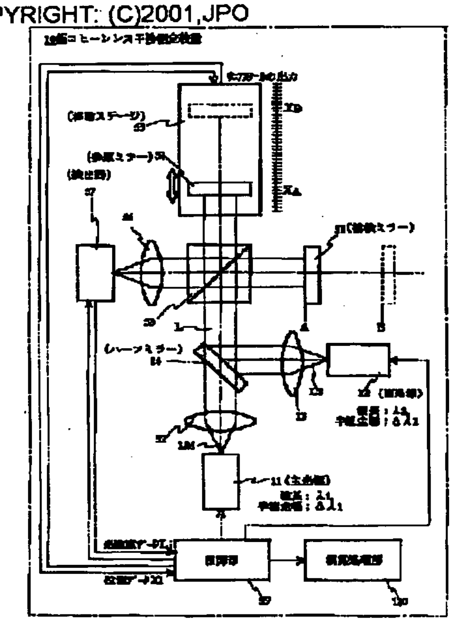
(54) **APPARATUS FOR MEASURING LOW COHERENCE INTERFERENCE**

(57) Abstract:

PROBLEM TO BE SOLVED: To achieve a higher accuracy with a steeper envelope of an interference characteristic curve by partially altering the structure of the conventional low coherence interference measuring apparatus.

SOLUTION: There are arranged a main light source as low-coherence light source, an interference optical system in which the luminous flux emitted from the main light source is divided to be guided to both a subject and a control object, while the subject light reflected on the subject and the control light reflected on the control object are made to overlap and caused interfere with each other, a support means for supporting the control object movably and a detection means to detect the intensity of the interference light produced from the subject light and the control light. Furthermore, a sub-light source, equipped with the center wavelength thereof different from that of the main light source, is provided and the luminous flux emitted from the sub-light source is made to overlap on the optical path of the luminous flux emitted from the main light source, before being divided in the optical path thereof by an integrated optical system. At this point, since beating is generated in the envelope of an interference characteristic curve attributed to the difference in the center wavelength between the two light sources a drop on both sides of a peak is produced, thereby making the inclination of the envelope steeper.



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(71)Applicant : NIKON CORP
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(54) APPARATUS FOR MEASURING LOW COHERENCE INTERFERENCE

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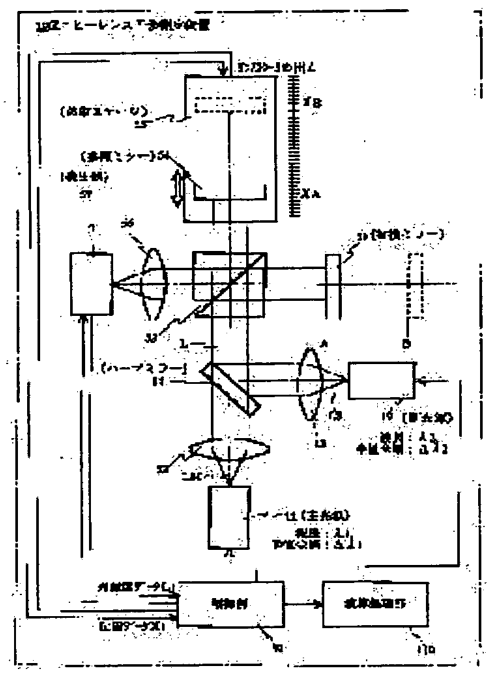

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CLAIMS

[Claim(s)]
[Claim 1] While dividing the flux of light by which outgoing radiation was carried out from the main light source which is characterized by providing the following, and which is the low coherence light source, and the aforementioned main light source and leading to the both sides of the specimen and a reference object The low coherence interference measuring device equipped with a detection means to detect the intensity of the interference light which the interference optical system in which double ****-ed reflected in the specimen and the reference beam reflected in the reference object in each-other pile, and it is made to interfere, the support means supported possible [movement of the aforementioned reference object], and the aforementioned ****-ed and a reference beam constitute. The sublight source with which main wavelength differs from the aforementioned main light source. Integrated optical system which lays the flux of light by which outgoing radiation was carried out from the aforementioned sublight source on top of the optical path before [above] division is carried out among the optical paths of the flux of light by which outgoing radiation was carried out from the aforementioned main light source.
[Claim 2] The low coherence interference measuring device according to claim 1 characterized by having the reference-by-location speciality stage which asks for the position of the aforementioned ****-ed on the basis of the position of the aforementioned reference object from change of the intensity of the aforementioned interference light which scans the position of the aforementioned reference object and the aforementioned detection means detects then.

[Translation done.]

* NOTICES *

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1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[The technical field to which invention belongs] this invention relates to a low coherence interference measuring device.
[0002]
[Description of the Prior Art] At many processes, such as processing of an optical instrument, inspection, and an assembly, an interference measuring device is used for the range measurement which investigates a position, an interval, etc. of an optical element. Especially, as compared with the wavelength of light, a low coherence interference measuring device is used for measurement of a long distance in many cases. Drawing 5 is drawing showing the conventional low coherence interference measuring device 50. Incidentally, what is shown in drawing 5 is the interference measuring device to which the Michelson type interferometer was applied.
[0003] The **-ed mirror 58 arranged by the low coherence interference measuring device 50 like a general interference measuring device at ****** A-ed, While dividing the light by which outgoing radiation was carried out into both sides with the reference mirror 54 laid on the move stage 55 and irradiating it from the same light source 51 to them ****-ed reflected in the **-ed mirror 58 and the reference beam reflected in the reference mirror 54 are piled up again, and a detector 57 detects the intensity of the interference light which both light constitutes.
[0004] Here, the light source 51 of the low coherence interference measuring device 50 is the low coherence light source with which coherence length carries out outgoing radiation of the light short enough. For example, a super luminescent diode (SLD) is used for this light source 51, and full-width-at-half-maximum deltalambda of the wavelength spectrum and the main wavelength lambda are set as the predetermined value (for example, deltalambda=7nm, lambda= 680nm), respectively.
[0005] Since the optical-path-length difference of ****-ed from the **-ed mirror 58 and the reference beam from the reference mirror 54 serves as intensity of the interference light of both light at this time and it appears, a control section 59 carries out the monitor of the output of a detector 57, scanning the position of the reference mirror 54, in order to detect a position of the reference mirror 54 where this optical-path-length difference becomes 0. At this time, each position data (output of the Linear Scale which it had in the move stage 55) Xi of the reference mirror 54, and the optical on-the-strength data Li (output of a detector 57) of an interference light in case the position data of a reference mirror are Xi are matched mutually.
[0006] Drawing 6 is drawing showing the optical-path-length difference-interference light strength property curve (henceforth an "interference characteristic curve") of the low coherence interference measuring device 50. An interference characteristic curve shows much extremal value, and the envelope (constant curve which the aforementioned interference characteristic curve touches) of an interference characteristic curve shows extremal value (the extremal value of an envelope is hereafter called "peak".) at the time of the optical-path-length difference 0 so that clearly [this drawing 6].
[0007] If the data-processing section 510 gives predetermined operations, such as smooth differential, to each survey data (Li, Xi) which the control section 59 obtained and the relation between the interference light intensity L and the position X of the reference mirror 54 is obtained to it, it will distinguish sharply the interference light intensity LA corresponding to the aforementioned peak. And it considers that the position XA of the reference mirror 54 which gives the value LA is the position which realizes the optical-path-length difference 0, and the value XA is memorized as a value which shows ****** A-ed.
[0008] The above operation is similarly performed in the state where the **-ed mirror 58 has been arranged to ****** B-ed, and the position XB of the reference mirror 54 which realizes the optical-path-length difference 0 is memorized as a value which shows ****** B-ed. Therefore, the interval of a position A and a position B is obtained by |XA-XB|. In addition, on these specifications, in this way, coherence length calls the light set up short "low coherence light", and fully calls the light source which carries out outgoing radiation of the low coherence light the "low coherence light source" so that a peak may occur in the aforementioned envelope at least in measuring range only at the time of the optical-path-length difference 0.
[0009]
[Problem(s) to be Solved by the Invention] By the way, in order to high-degree-of-accuracy-ize the low coherence interference measuring device 50 explained above, it is necessary to detect correctly the interference light intensity LA corresponding to the state, i.e., the aforementioned peak, where the optical-path-length difference of ****-ed and a reference beam is set to 0. for that purpose -- although what is necessary is just to acquire each optical on-the-strength data Li in sufficient precision -- the optical intensity of a detector 57 -- it is very difficult to raise resolution as everyone knows

[0010] Then, in order to compress an error, it is possible to apply data processing, such as the least square method, to each survey data (Li, Xi). However, the data-processing section 510 is complicated in this case, and the fall of processing speed is not avoided. Moreover, though it is permitted, if each optical on-the-strength data Li is not acquired at all in sufficient precision, there is a limitation in compression of the error by the operation.
[0011] If the wavelength spectral band width of the light source 51 is extended and the coherence length is shortened further, since the full width at half maximum of the envelope of an interference characteristic curve will narrow on the other hand, interference light intensity will change a lot around a peak, and it becomes easy to detect the state of the optical-path-length difference 0. However, since directivity falls [extending wavelength spectral band width (that is, it bringing close to the white light)], it becomes difficult to apply a general light to equipment.
[0012] Then, this invention aims at offering the low coherence interference measuring device which the inclination of the aforementioned envelope was made to turn steeply and was high-degree-of-accuracy-ized by changing a part of composition of the conventional low coherence interference measuring device.
[0013]
[Means for Solving the Problem] A low coherence interference measuring device according to claim 1 or 2 While having the main light source which is the low coherence light source, dividing the flux of light by which outgoing radiation was carried out from the main light source and leading to the both sides of the specimen and a reference object It has a detection means to detect the intensity of the interference light which the interference optical system in which double ****-ed reflected in the specimen and the reference beam reflected in the reference object in each-other pile, and it is made to interfere, the support means supported possible [movement of the aforementioned reference object], and the aforementioned ****-ed and a reference beam constitute. Furthermore, this low coherence interference measuring device was equipped with the sublight source with which main wavelength differs from the aforementioned main light source, and has laid the flux of light by which outgoing radiation was carried out from the aforementioned sublight source on top of the optical path before [above] division is carried out with integrated optical system among the optical paths of the flux of light by which outgoing radiation was carried out from the aforementioned main light source.
[0014] The interference light intensity produced under the two above-mentioned light sources serves as the sum of the interference light intensity produced when the main light source is used independently, and the interference light intensity produced when the sublight source is used independently. Therefore, in the envelope of the interference characteristic curve of this low coherence interference measuring device, a peak occurs [an optical-path-length difference] in the state of 0 as usual. However, since a beat arises according to the difference in the main wavelength of the two light sources, depression arises on both sides of the aforementioned peak, and the inclination of an envelope turns into this envelope steeply.
[0015] And in a low coherence interference measuring device according to claim 2, the position of the aforementioned reference object is scanned and it asks for the position of the aforementioned specimen on the basis of the position of the aforementioned reference object from change of the intensity of the aforementioned interference light which the aforementioned detection means detects then. In this low coherence interference measuring device into which the inclination of the envelope of an interference characteristic curve turned steeply as mentioned above, interference light intensity changes a lot around the optical-path-length difference 0. Therefore, the state of the optical-path-length difference 0 is certainly distinguishable from change of the intensity of an interference light. And if the position of the reference object in this state is referred to, the position of the specimen will be called for with high precision.
[0016]
[Embodiments of the Invention] Hereafter, the operation form of this invention is explained based on a drawing. Drawing 1 is drawing showing the low coherence interference measuring device 10 of this operation form. In addition, in drawing 1 , the same sign is attached and shown about the same part as the conventional low coherence interference measuring device 50 shown in drawing 5 .
[0017] In the low coherence interference measuring device 10, the main differences with the conventional low coherence interference measuring device 50 are points that the sublight source 12, the collimator lens 13, and the one-way mirror 14 are added. Namely, the low coherence interference measuring device 10 Two collimator lenses corresponding to the two light sources (the main light source 11, sublight source 12) and each light source (collimator lenses 52 and 13), A one-way mirror 14 (it corresponds to integrated optical system), a beam splitter 53 (it corresponds to an interference optical system), The **-ed mirror 58 (it corresponds to the specimen), the reference mirror 54 (it corresponds to a reference object), It has a condenser lens 56, a detector 57 (it corresponds to a detection means), the move stage 55 (it corresponds to support means), a control section 59 (it corresponds to the reference-by-location speciality stage), and the data-processing section 110 (it corresponds to the reference-by-location speciality stage).
[0018] In this low coherence interference measuring device 10, the flux of light LM injected from the main light source 11 is changed into the parallel flux of light by the collimator lens 52. Moreover, the flux of light LS injected from the sublight source 12 is changed into the parallel flux of light by the collimator lens 13. Through a one-way mirror 14, these flux of lights LM and flux of lights LS are led to the same optical path, are piled up, and turn into the flux of light L. The flux of light L is divided by the beam splitter 53, a part is led to the **-ed mirror 58, and other parts are led to the reference mirror 54. Incidence of ****-ed reflected in the **-ed mirror 58 and the reference beam reflected in the reference mirror 54 is again carried out to a beam splitter 53, and it makes an interference light occur on a detector 57 through a condenser lens 56 after that.
[0019] Moreover, the reference mirror 54 is installed on the move stage 55. The move stage 55 of a bird clapper is movable in the direction of an optical axis from the rectilinear-propagation stage of a stepping motor drive etc. with a control section 59. Moreover, the Linear Scale (un-illustrating) which detects the position of the direction of an optical axis of the move stage 55 is carried in this move stage 55, and the signal which shows the position is outputted as

position data Xi in which the position of the reference mirror 54 is shown.
[0020] Moreover, a detector 57 consists of the photomultiplier tube which detects the luminous intensity which carried out incidence, and outputs the optical on-the-strength data Li in which the intensity of an interference light is shown according to directions of a control section 59. Drawing 2 is drawing showing the wavelength spectrum distribution of the main light source 11 and the sublight source 12. The main light source 11 of this operation gestalt is the low coherence light source as well as the conventional light source 51 (refer to drawing 5). The super luminescent diode (SLD) which carried out the gauss type wavelength spectrum distribution is used for the main light source 11, and the full width at half maximum deltalambda1 of a wavelength spectrum and the main wavelength lambda 1 are set as a predetermined value (for example, deltalambda1=7nm, lambda1=680nm), respectively.
[0021] On the other hand, the sublight source 12 is the light source with which the main wavelength lambda 2 was set as the predetermined value from which the main wavelength lambda 1 of the main light source 11 differs. The HeNe laser (deltalambda2**0nm lambda 2= 632.8nm) of single wavelength is used for the sublight source 12. And an incoherent (incoherent) relation is realized between this sublight source 12 and the main light source 11.
[0022] The interference light intensity produced under these two light sources serves as the sum of the interference light intensity (refer to drawing 6) produced when the main light source 11 is used independently, and the interference light intensity (it is the mere sine function of an optical-path-length difference) produced when the sublight source 12 is used independently.
[0023] Drawing 3 is drawing showing the interference characteristic curve of the low coherence interference measuring device 10. Therefore, in the envelope of the interference characteristic curve of this operation gestalt, a peak (the maximum peak) occurs in the state of the optical-path-length difference 0 as usual so that clearly [drawing 3]. However, since main wavelength differs, in the envelope of this operation gestalt, the beat has produced the two light sources. This beat is generated at the interval (L5=1/deltaD) according to wave number difference deltaD between the main light source 11 and the sublight source 12 (deltaD=|(1/lambda 1)-(1/lambda 2) |).
[0024] For this reason, depression arose on both sides of the maximum peak corresponding to the optical-path-length difference 0, and the inclination of an envelope has turned into them steeply. In addition, in this envelope, a little small peak occurs besides the maximum peak corresponding to the optical-path-length difference 0. However, with this operation gestalt, in order to distinguish the maximum peak sharply certainly, beforehand, the value of the main wavelength lambda1 and lambda2 of the main light source 11 and the sublight source 12 is chosen as a suitable relation, and on-the-strength difference deltaL of the maximum peak corresponding to the optical-path-length difference 0 and the peak (contiguity peak) which adjoins it is secured to the size of a grade detectable [with a detector 57].
[0025] It returns to drawing 1 , and in the low coherence interference measuring device 10, in case the interval of ****** A-ed and ****** B-ed is measured, as usual, the **-ed mirror 58 is arranged at each of ****** A-ed and ****** B-ed, and the values XA and XB which show ****** A and B-ed are acquired individually. Namely, in the state where the **-ed mirror 58 has been arranged at ****** A-ed, a control section 59 carries out the monitor of the output of a detector 57, driving the main light source 11, the sublight source 12, the move stage 55, and a detector 57, and scanning the position of the reference mirror 54, matches mutually each position data Xi of the reference mirror 54, and each optical on-the-strength data Li of an interference light, and gives them to the data-processing section 110.
[0026] As mentioned above, since the inclination of the envelope of an interference characteristic curve has turned steeply, with this operation form, the intensity of an interference light should turn strangely greatly around the optical-path-length difference 0. For this reason, the change in the circumference of the optical-path-length difference 0 also with with each optical big on-the-strength data Li which is survey data is shown.
[0027] Therefore, with this operation form, the sharp-distinction precision of the interference light intensity LA corresponding to the optical path difference 0 only in the part into which the inclination of the aforementioned envelope turned steeply even if though the contents of an operation in the data-processing section 110 were the same as the former increases, and the accuracy of measurement of the position XA A which shows the optical-path-length difference 0, i.e., ******-ed, increases. Incidentally, if the operation in the data-processing section 110 gives predetermined operations, such as smooth differential, to each survey data (Li, Xi) and the relation between the interference light intensity L and the position X of the reference mirror 54 is obtained to it, it will consider that the maximum interference light intensity LA is a value corresponding to the aforementioned maximum peak, and it will distinguish it sharply, for example. And it considers that the position XA of the reference mirror 54 which gives the value LA is the position which realizes the optical-path-length difference 0, and the value XA is memorized as a value which shows ****** A-ed. To a pan When attaining highly precise-ization, the data-processing section 110 is made to memorize beforehand the configuration information which shows the configuration (refer to drawing 3) of an interference characteristic curve, or the configuration of the envelope. And the data-processing section 110 should just remove a measurement error from the relation between the interference light intensity L and the position X of the reference mirror 54 by applying data processing based on the configuration information, such as the least square method, to each survey data (Li, Xi).
[0028] Anyway, with this operation form, as for the accuracy of measurement of ****** A-ed, only the part into which the inclination of the envelope of an interference characteristic curve turned steeply increases. And the above operation is similarly performed in the state where the **-ed mirror 58 has been arranged to ****** B-ed, and the position XB of the reference mirror 54 which realizes the optical-path-length difference 0 is memorized as a value which shows ****** B-ed. With this operation form, only the part into which the inclination of the aforementioned envelope turned steeply increases also about the accuracy of measurement of ****** B-ed. And as a result, interval |XA-XB| of a position A and a position B is obtained with high precision.
[0029] As explained above, composition of this operation form is certainly high-degree-of-accuracy-ized, although the sublight source 12 was only mainly added to the conventional low coherence interference measuring device 50. in

addition -- although the low coherence light source is used for the main light source 11 and the coherence light source is used for the sublight source 12 with the above-mentioned operation form -- as these light sources -- both main wavelength -- differing -- it is even (lambda1 !=lambda2) -- if it carries out, it is desirable to, make large each of the wavelength spectral band width of the main light source 11 and the wavelength spectral band width of the sublight source 12 if possible, unless the directivity is lost generally, full-width-at-half-maximum deltaX of the envelope of an interference characteristic curve becomes so small that full-width-at-half-maximum deltalambda of the wavelength spectrum distribution of the light source is large (incidentally in the case of the single light source, deltaX=0.693/(pideltanu), however deltanu are the full width at half maximum when assuming the wavelength spectrum distribution of the light source to be Gaussian distribution, and expressing as a function of the wave number nu.) -- it is -- if it does in this way, the both sides of the maximum peak can be made to fall more steeply

[0030] Moreover, in the above-mentioned operation gestalt, it is desirable to take wave number difference deltaD (deltaD=|(1/lambda 1)-(1/lambda 2) |) of both the light sources large enough. Since the interval L5 (L5=1/deltaD) of the peaks of an envelope becomes small so that wave number difference deltaD becomes large, the both sides of the maximum peak can be made to fall more steeply. Moreover, in the above-mentioned operation gestalt, it is good also as shortening each of the main wavelength lambda1 and lambda2 of both the light sources, and asking for the relation between the interference light intensity L and the position X of the reference mirror 54 more flexibly according to the precision of the move stage 55 or a detector 57 increasing.

[0031] Moreover, in the above-mentioned operation gestalt, about how of the flux of light LM by which outgoing radiation was carried out from the main light source 11, and the flux of light LS by which outgoing radiation was carried out from the sublight source 12 to pile up, as long as these flux of lights LM and LS are led to the same optical path, you may adopt what method. In addition, in the above-mentioned operation gestalt, a control section 59 or the data-processing section 110 does not need to be built in the low coherence interference measuring device 10. For example, it may replace with the data-processing section 110, and the same processing as an external computer may be made to perform.

[0032] Moreover, in the profile irregularity measurement as which a high precision is required, this invention explained above is suitable, when measuring the interval of the optical element of a specific kind. Hereafter, the case where the above-mentioned low coherence interference measuring device 10 is applied to profile irregularity measurement is explained as other operation gestalten of this invention.

[0033] Drawing 4 is drawing explaining other operation forms. First, the profile irregularity measuring device 40 is used for profile irregularity measurement. The profile irregularity measuring device 40 irradiates the light of a predetermined wave front also at reference side 45a, and detects the interference fringe which the reflected light in both fields accomplishes with the two-dimensional picture detector 410 while it irradiates the light of a predetermined wave front like the low coherence interference measuring device 10 at specimen plane 40a in order to observe profile irregularity in two dimensions, although it is equipment using interference of light. The profile irregularity of specimen plane 40a can be obtained by analyzing the pattern of the interference fringe in an arithmetic unit 411.

[0034] Here, when the design configuration of specimen plane 40a is the aspheric surface, the profile irregularity measuring device 40 may set the wave front of the light which irradiates specimen plane 40a as an aspheric surface configuration to correspond to it. however, even if such a light advances, unlike the spherical wave to which the wave-front configuration is not changed, it advances -- since it is alike, and it follows and the wave-front configuration is changed -- the relation between the position A of specimen plane 40a, and the position B of the profile irregularity measuring device 40 -- the direction of an optical axis -- only -- also coming out -- if it shifts, the state of the light which carries out incidence to specimen plane 40a will change a lot, and a measurement error will arise In order to abolish a measurement error, it is necessary to measure the interval of specimen plane 40a and the profile irregularity measuring device 40.

[0035] Then, with this operation form, the above-mentioned low coherence interference measuring device 10 is applied to this measurement. However, an arithmetic unit 411 asks for the profile irregularity of specimen plane 40a based on the pattern of the acquired interference fringe, and the interval which the low coherence interference measuring device 10 measured at this time. Since highly precise range measurement is possible according to the low coherence interference measuring device 10 as mentioned above, this profile irregularity measurement as which the precision of under the wavelength of light is required can be made to high-degree-of-accuracy-ize certainly.

[0036] In addition, if the information which the low coherence interference measuring device 10 gives to an arithmetic unit 411 is information which shows the interval of a position A and a position B, it is good as information on any forms, such as combination of the value XA which shows the position A besides value |XA-XB| which shows an interval, and the value XB which shows a position B, and combination of the optical on-the-strength data Li and the position data Xi. Moreover, you may be that the measurement result of the low coherence interference measuring device 10 is used at the time of the alignment of specimen plane 40a and the profile irregularity measuring device 40.

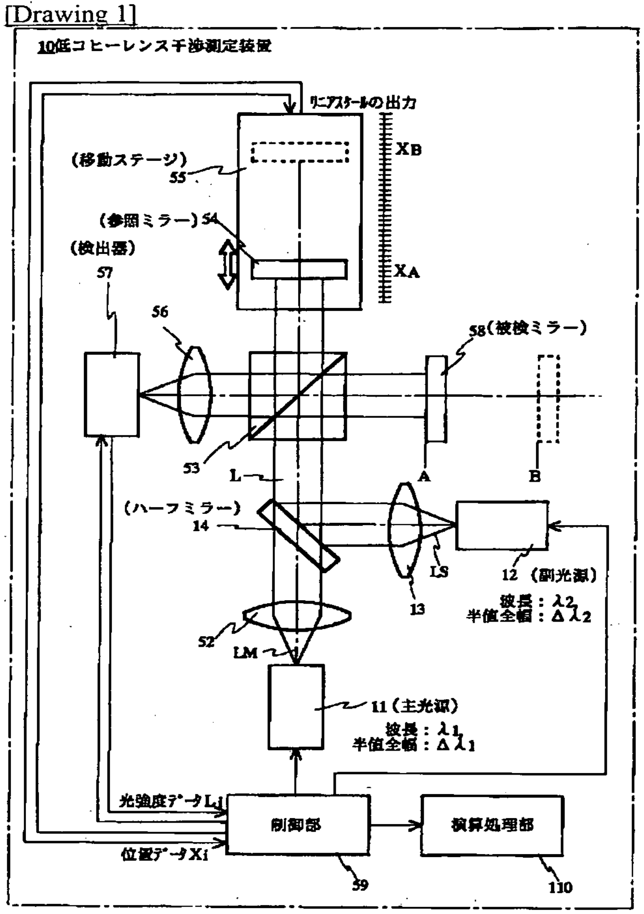
[0037]

[Effect of the Invention] As explained above, according to this invention, the inclination of the envelope of an interference characteristic curve turns steeply only by adding change to conventional equipment in part, and a highly precise low coherence interference measuring device is realized by this.

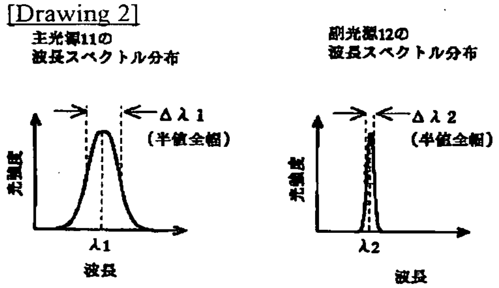
[Translation done.]

DRAWINGS

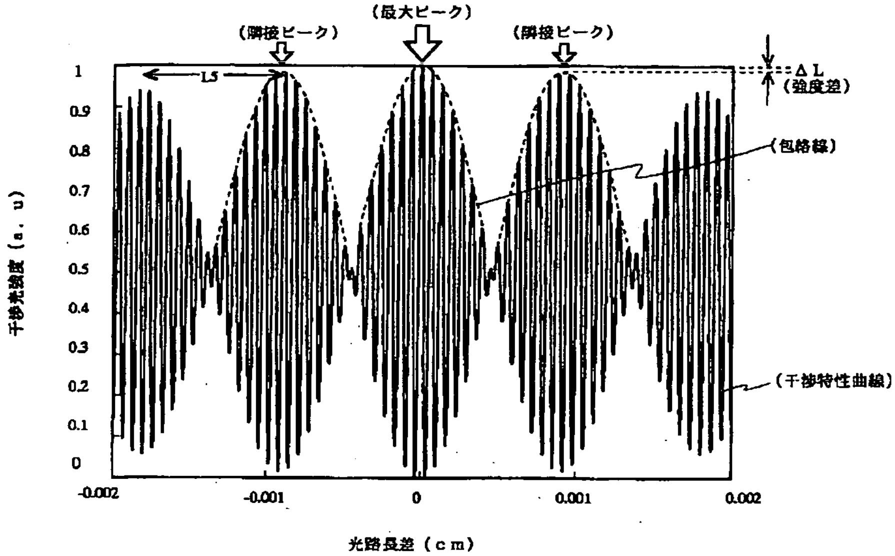
[Drawing 1]



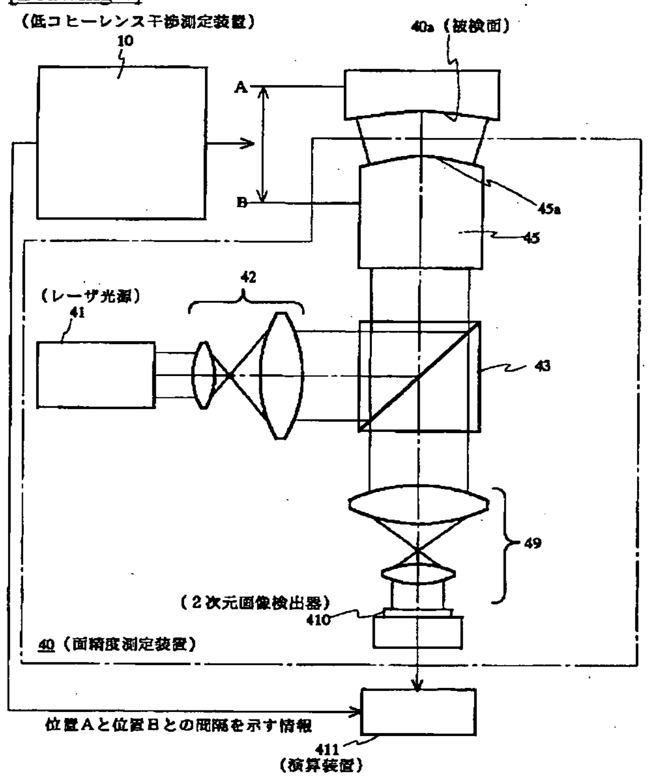
[Drawing 2]



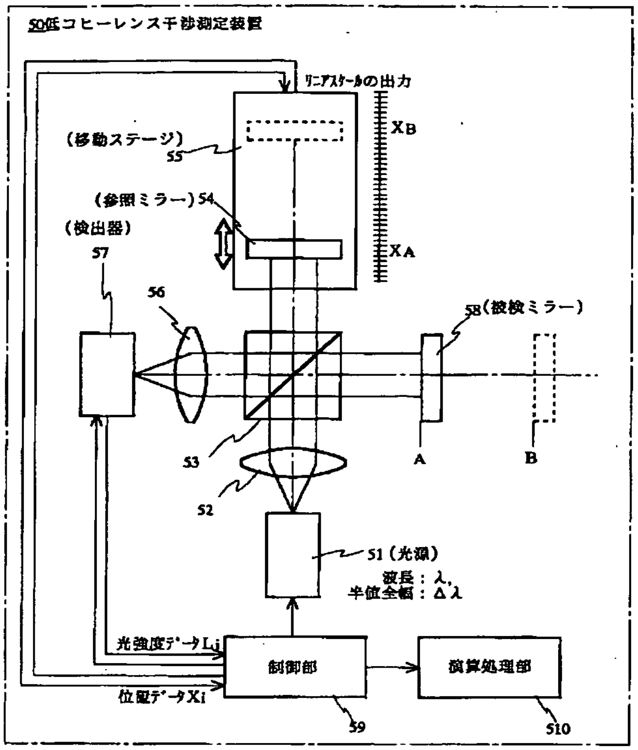
[Drawing 3]



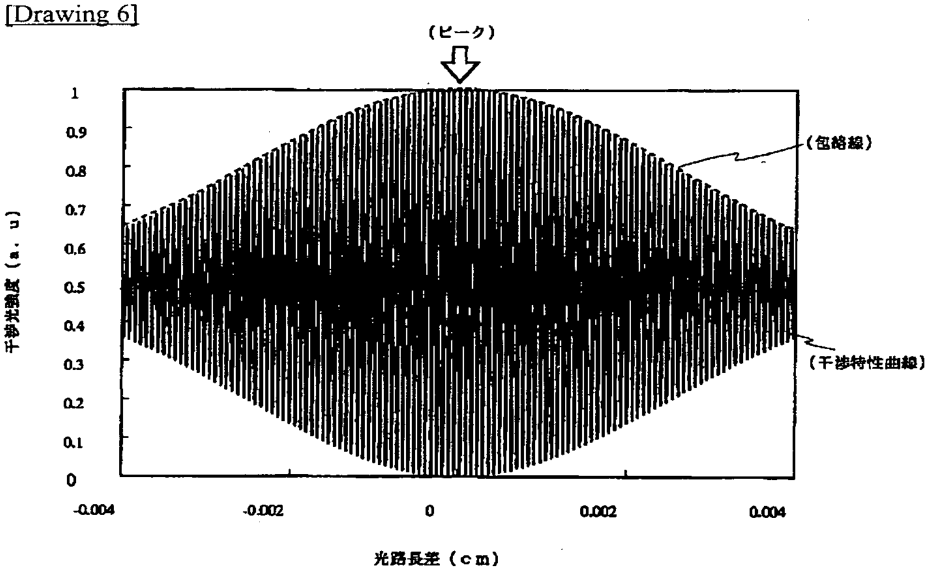
[Drawing 4]



[Drawing 5]



[Drawing 6]



[Translation done.]

Page 1 of 1

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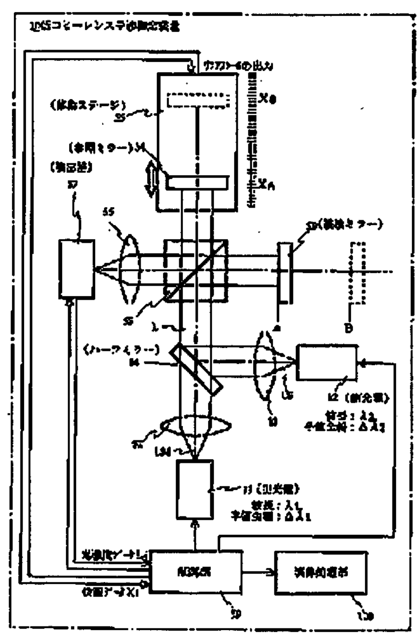
最終頁に続く

(54)【発明の名称】　低コヒーレンス干渉測定装置

(57)【要約】

【課題】　従来の低コヒーレンス干渉測定装置の構成を一部変更して干渉特性曲線の包絡線を急峻化させ、高精度化を図ることを目的とする。

【解決手段】　低コヒーレンス光源である主光源と、主光源から出射された光束を分割し、被検物と参照物との双方に導くと共に、被検物において反射した被検光と参照物において反射した参照光とを、互い重ね合わせて干渉させる干渉光学系と、参照物を移動可能に支持する支持手段と、被検光と参照光とが成す干渉光の強度を検出する検出手段とを備える。さらに、主光源とは中心波長の異なる副光源を備え、副光源から出射された光束を、統合光学系によって、主光源から出射された光束の光路のうち、分割される前の光路に重ね合わせている。このとき、干渉特性曲線の包絡線には、2つの光源の中心波長の差異によってうなりが生じるので、ピークの両側には落ち込みが生じ、包絡線の傾きが急峻化される。



【特許請求の範囲】

【請求項１】 低コヒーレンス光源である主光源と、前記主光源から出射された光束を分割し、被検物と参照物との双方に導くと共に、被検物において反射した被検光と参照物において反射した参照光とを、互い重ね合わせて干渉させる干渉光学系と、

前記参照物を移動可能に支持する支持手段と、

前記被検光と参照光とが成す干渉光の強度を検出する検出手段とを備えた低コヒーレンス干渉測定装置において、

前記主光源とは中心波長の異なる副光源と、

前記副光源から出射された光束を、前記主光源から出射された光束の光路のうち、前記分割される前の光路に重ね合わせる統合光学系とを備えたことを特徴とする低コヒーレンス干渉測定装置。

【請求項２】 前記参照物の位置を走査し、そのときに前記検出手段が検出する前記干渉光の強度の変化から、前記参照物の位置を基準とした前記被検物の位置を求める位置取得手段を備えたことを特徴とする請求項１記載の低コヒーレンス干渉測定装置。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、低コヒーレンス干渉測定装置に関する。

【０００２】

【従来の技術】光学機器の加工、検査、組立てなどの多くの工程では、光学素子の位置や間隔などを調べる距離測定に、干渉測定装置が使用される。特に、光の波長と比較して長い距離の測定には、低コヒーレンス干渉測定装置が使用されることが多い。図５は、従来の低コヒーレンス干渉測定装置５０を示す図である。因みに、図５に示すのは、マイケルソン型の干渉計が適用された干渉測定装置である。

【０００３】低コヒーレンス干渉測定装置５０は、一般的な干渉測定装置と同様、被検位置Ａに配置された被検ミラー５８と、移動ステージ５５上に載置された参照ミラー５４との双方に、同一の光源５１から出射された光を分割して照射すると共に、被検ミラー５８において反射した被検光と、参照ミラー５４において反射した参照光とを再び重ね合わせ、両光が成す干渉光の強度を検出器５７により検出するものである。

【０００４】ここで、低コヒーレンス干渉測定装置５０の光源５１は、可干渉距離が十分に短い光を出射する低コヒーレンス光源である。この光源５１には、例えば、スーパールミネッセントダイオード（ＳＬＤ）が使用され、その波長スペクトルの半値全幅Δλ、中心波長λがそれぞれ所定値（例えば、Δλ＝７ｎｍ、λ＝６８０ｎｍ）に設定されている。

【０００５】このとき、被検ミラー５８からの被検光と参照ミラー５４からの参照光との光路長差は、両光の干渉光の強度となって現れるので、制御部５９は、この光路長差が０となるような参照ミラー５４の位置を検知するために、参照ミラー５４の位置を走査しながら検出器５７の出力をモニタする。このとき、参照ミラー５４の各位置データ（移動ステージ５５内に備えられたリニアスケールの出力）X_1と、参照ミラーの位置データがX_iであるときの干渉光の光強度データL_i（検出器５７の出力）とは、互いに対応づけられる。

【０００６】図６は、低コヒーレンス干渉測定装置５０の光路長差−干渉光強度特性曲線（以下「干渉特性曲線」という。）を示す図である。この図６に明らかなように、干渉特性曲線は多数の極値を示し、干渉特性曲線の包絡線（前記干渉特性曲線が接する定曲線）は光路長差０のときに極値（以下、包絡線の極値を「ピーク」という。）を示す。

【０００７】演算処理部５１０は、制御部５９が得た各実測データ（L_i，X_i）に、例えば平滑微分などの所定の演算を施して、干渉光強度Ｌと参照ミラー５４の位置Ｘとの関係を得ると、前記ピークに対応する干渉光強度L_Aを検別する。そして、その値L_Aを与える参照ミラー５４の位置X_Aを、光路長差０を実現する位置とみなし、その値X_Aを、被検位置Ａを示す値として記憶する。

【０００８】以上の動作は、被検ミラー５８を被検位置Ｂに配置した状態でも同様に行われ、光路長差０を実現する参照ミラー５４の位置X_Bが、被検位置Ｂを示す値として記憶される。したがって、位置Ａと位置Ｂとの間隔は、$|X_A-X_B|$により得られる。なお、本明細書では、このように、少なくとも測定範囲においては光路長差０のときにのみ前記包絡線にピークが発生するよう、十分に可干渉距離が短く設定された光を「低コヒーレンス光」と称し、低コヒーレンス光を出射する光源を「低コヒーレンス光源」と称する。

【０００９】

【発明が解決しようとする課題】ところで、以上説明した低コヒーレンス干渉測定装置５０を高精度化するには、被検光と参照光との光路長差が０となる状態、つまり、前記ピークに対応する干渉光強度L_Aを正確に検知する必要がある。そのためには、各光強度データL_1を十分な精度で取得すればよいが、検出器５７の光強度分解能を向上させるのは、周知のとおり非常に困難である。

【００１０】そこで、誤差を圧縮するために、各実測データ（L_1，X_1）に最小二乗法などの演算処理を適用することが考えられる。しかしこの場合、演算処理部５１０が複雑化し、かつ処理速度の低下が避けられない。また、仮にそれを許容したとしても、各光強度データL_1が十分な精度で取得されない以上は、演算による誤差の圧縮には限界がある。

【００１１】一方、光源５１の波長スペクトル幅を広げ

てその可干渉距離をさらに短くすれば、干渉特性曲線の包絡線の半値全幅が狭まるので、ピーク周辺で干渉光強度が大きく変化することとなり、光路長差0の状態を検知し易くなる。しかし、一般の光は、波長スペクトル幅を広げる（すなわち白色光に近づける）ほど指向性が低下するので、装置への適用が困難となる。

【0012】そこで本発明は、従来の低コヒーレンス干渉測定装置の構成を一部変更することにより前記包絡線の傾きを急峻化させて、高精度化された低コヒーレンス干渉測定装置を提供することを目的とする。

【0013】

【課題を解決するための手段】請求項1または請求項2に記載の低コヒーレンス干渉測定装置は、低コヒーレンス光源である主光源を備え、その主光源から出射された光束を分割し、被検物と参照物との双方に導くと共に、被検物において反射した被検光と参照物において反射した参照光とを、互い重ね合わせて干渉させる干渉光学系と、前記参照物を移動可能に支持する支持手段と、前記被検光と参照光とが成す干渉光の強度を検出する検出手段とを備える。さらに、この低コヒーレンス干渉測定装置は、前記主光源とは中心波長の異なる副光源を備え、前記副光源から出射された光束を、統合光学系によって、前記主光源から出射された光束の光路のうち、前記分割される前の光路に重ね合わせている。

【0014】上記2つの光源の下で生じる干渉光強度は、主光源を単独で用いた場合に生じる干渉光強度と、副光源を単独で用いた場合に生じる干渉光強度との和となる。したがって、この低コヒーレンス干渉測定装置の干渉特性曲線の包絡線には、従来と同様、光路長差が0の状態においてピークが発生する。ただし、この包絡線には、2つの光源の中心波長の差異によってうなりが生じるので、前記ピークの両側には落ち込みが生じ、包絡線の傾きが急峻化される。

【0015】そして、請求項2に記載の低コヒーレンス干渉測定装置では、前記参照物の位置を走査し、そのときに前記検出手段が検出する前記干渉光の強度の変化から、前記参照物の位置を基準とした前記被検物の位置を求める。上記のように干渉特性曲線の包絡線の傾きが急峻化されたこの低コヒーレンス干渉測定装置では、光路長差0の周辺で干渉光強度が大きく変化する。したがって、干渉光の強度の変化から光路長差0の状態を確実に峻別することができる。そして、この状態での参照物の位置を参照すれば、被検物の位置は高精度に求められる。

【0016】

【発明の実施の形態】以下、図面に基づいて本発明の実施形態について説明する。図1は、本実施形態の低コヒーレンス干渉測定装置10を示す図である。なお、図1において、図5に示した従来の低コヒーレンス干渉測定装置50と同じ箇所については、同一の符号を付して示している。

【0017】低コヒーレンス干渉測定装置10において、従来の低コヒーレンス干渉測定装置50との主な相違点は、副光源12、コリメータレンズ13、およびハーフミラー14が付加されている点である。すなわち、低コヒーレンス干渉測定装置10は、二つの光源（主光源11、副光源12）、それぞれの光源に対応する2つのコリメータレンズ（コリメータレンズ52、13）、ハーフミラー14（統合光学系に対応する）、ビームスプリッタ53（干渉光学系に対応する）、被検ミラー58（被検物に対応する）、参照ミラー54（参照物に対応する）、集光レンズ56、検出器57（検出手段に対応する）、移動ステージ55（支持手段に対応する）、制御部59（位置取得手段に対応する）、および演算処理部110（位置取得手段に対応する）を備えている。

【0018】この低コヒーレンス干渉測定装置10において、主光源11から射出した光束LMはコリメータレンズ52により平行光束に変換される。また、副光源12から射出した光束LSはコリメータレンズ13により平行光束に変換される。これらの光束LMと光束LSとは、ハーフミラー14を介して同一光路に導かれて重ね合わされ、光束Lとなる。光束Lは、ビームスプリッタ53により分割され、一部が被検ミラー58へ導かれ、他の一部が参照ミラー54へと導かれる。被検ミラー58において反射した被検光と、参照ミラー54において反射した参照光とは再びビームスプリッタ53へ入射し、その後集光レンズ56を介して検出器57上に干渉光を生起させる。

【0019】また、参照ミラー54は、移動ステージ55上に設置されている。ステッピングモータ駆動の直進ステージなどからなるこの移動ステージ55は、制御部59によって光軸方向に移動可能である。また、この移動ステージ55には、移動ステージ55の光軸方向の位置を検出するリニアスケール（不図示）が搭載されており、その位置を示す信号が、参照ミラー54の位置を示す位置データXiとして出力される。

【0020】また、検出器57は、入射した光の強度を検出する光電子増倍管などからなり、制御部59の指示に応じて干渉光の強度を示す光強度データL_iを出力する。図2は、主光源11、副光源12の波長スペクトル分布を示す図である。本実施形態の主光源11は、従来の光源51（図5参照）と同様、低コヒーレンス光源である。主光源11には、例えば、ガウス型の波長スペクトル分布をした、スーパールミネッセントダイオード（SLD）が使用され、波長スペクトルの半値全幅Δλ1、中心波長λ1がそれぞれ所定値（例えば、Δλ1＝7nm、λ1＝680nm）に設定される。

【0021】一方、副光源12は、その中心波長λ2が、主光源11の中心波長λ1とは異なる所定値に設定された光源である。副光源12には、例えば、単一波長

のHeNeレーザ（$\Delta\lambda 2 \fallingdotseq 0$nm、$\lambda 2=632.8$nm）が使用される。そして、この副光源12と、主光源11との間では、非干渉性（インコヒーレント）の関係が成り立つ。

【0022】これら2つの光源の下で生じる干渉光強度は、主光源11を単独で用いた場合に生じる干渉光強度（図6参照）と、副光源12を単独で用いた場合に生じる干渉光強度（光路長差の単なる正弦関数である）との和となる。

【0023】図3は、低コヒーレンス干渉測定装置10の干渉特性曲線を示す図である。したがって、図3に明らかなように、本実施形態の干渉特性曲線の包絡線には、従来と同様、光路長差0の状態においてピーク（最大ピーク）が発生する。但し、2つの光源は中心波長が異なるので、本実施形態の包絡線には、うなりが生じている。このうなりは、主光源11と副光源12との間の波数差ΔD（$\Delta D=|(1/\lambda 1)-(1/\lambda 2)|$）に応じた間隔（$L5=1/\Delta D$）で発生している。

【0024】このため、光路長差0に対応する最大ピークの両側には、落ち込みが生じ、包絡線の傾きが急峻化されている。なお、この包絡線には、光路長差0に対応する最大ピークの他に、やや小さなピークが発生する。しかし、本実施形態では最大ピークを確実に峻別するために、予め主光源11および副光源12の中心波長$\lambda 1$、$\lambda 2$の値は適当な関係に選択され、光路長差0に対応する最大ピークとそれに隣接するピーク（隣接ピーク）との強度差ΔLは、検出器57によって検出可能な程度の大きさに確保されている。

【0025】図1に戻り、低コヒーレンス干渉測定装置10では、被検位置Aと被検位置Bとの間隔を測定する際に、従来と同様、被検位置A、被検位置Bのそれぞれに被検ミラー58が配置され、被検位置A、Bを示す値X_A、X_Bが個別に取得される。すなわち、被検位置Aに被検ミラー58が配置された状態で、制御部59は、主光源11、副光源12、移動ステージ55、および検出器57を駆動し、参照ミラー54の位置を走査しながら検出器57の出力をモニタして、参照ミラー54の各位置データX_1と、干渉光の各光強度データL_iとを互いに対応づけて演算処理部110に与える。

【0026】上述したように、本実施形態では、干渉特性曲線の包絡線の傾きが急峻化されているので、光路長差0の周辺では干渉光の強度が大きく変化すはずである。このため、実測データである各光強度データL_1も、光路長差0の周辺で大きな変化を示す。

【0027】したがって、本実施形態では、たとえ演算処理部110における演算内容が従来と同じであったとしても、前記包絡線の傾きが急峻化された分だけ、光路差0に対応する干渉光強度L_Aの峻別精度は高まり、光路長差0を示す位置X_A、すなわち被検位置Aの測定精度が高まる。因みに、演算処理部110における演算は、各実測データ（L_1、X_1）に、例えば平滑微分などの所定の演算を施して、干渉光強度Lと参照ミラー54の位置Xとの関係を得ると、例えば最大の干渉光強度L_Aを前記最大ピークに対応する値とみなして峻別する。そして、その値L_Aを与える参照ミラー54の位置X_Aを、光路長差0を実現する位置とみなし、その値X_Aを、被検位置Aを示す値として記憶するものである。さらに、高精度化を図る場合には、演算処理部110に、予め、干渉特性曲線の形状（図3参照）、またはその包絡線の形状を示す形状情報を記憶させる。そして、演算処理部110は、その形状情報に基づく最小二乗法などの演算処理を各実測データ（L_1、X_1）に適用することによって、干渉光強度Lと参照ミラー54の位置Xとの関係から、測定誤差を除去すればよい。

【0028】何れにせよ、本実施形態では、干渉特性曲線の包絡線の傾きが急峻化された分だけ、被検位置Aの測定精度は高まる。そして、以上の動作は被検ミラー58を被検位置Bに配置した状態でも同様に行われ、光路長差0を実現する参照ミラー54の位置X_Bが、被検位置Bを示す値として記憶される。本実施形態では、被検位置Bの測定精度についても、前記包絡線の傾きが急峻化された分だけ高まる。そしてその結果、位置Aと位置Bとの間隔$|X_A-X_B|$は、高精度に得られる。

【0029】以上説明したように、本実施形態の構成は、従来の低コヒーレンス干渉測定装置50に、主として副光源12を付加しただけであるが、確実に高精度化される。なお、上記実施形態では、主光源11に低コヒーレンス光源が用いられ、かつ副光源12にコヒーレンス光源が用いられているが、これらの光源としては、両者の中心波長が異なって（$\lambda 1 \neq \lambda 2$）いさえすれば、主光源11の波長スペクトル幅と、副光源12の波長スペクトル幅とのそれぞれを、その指向性が失われない限りにおいてなるべく広くすることが好ましい。一般に、干渉特性曲線の包絡線の半値全幅ΔXは、光源の波長スペクトル分布の半値全幅$\Delta\lambda$が大きいほど小さくなる（因みに、単一光源の場合、$\Delta X=0.693/(\pi\Delta\nu)$、但し$\Delta\nu$は光源の波長スペクトル分布をガウス分布と仮定し波数νの関数として表したときの半値全幅である。）ので、このようにすれば、最大ピークの両側を、より急峻に落ち込ませることができる。

【0030】また、上記実施形態においては、両光源の波数差ΔD（$\Delta D=|(1/\lambda 1)-(1/\lambda 2)|$）を十分に大きくとることが好ましい。波数差$\Delta D$が大きくなるほど、包絡線のピーク同士の間隔L5（$L5=1/\Delta D$）が小さくなるので、最大ピークの両側を、より急峻に落ち込ませることができる。また、上記実施形態においては、移動ステージ55や検出器57の精度が高まるのに応じて、両光源の中心波長$\lambda 1$、$\lambda 2$のそれぞれを短くして、干渉光強度Lと参照ミラー54の位置Xとの関係を、より柔軟に求めることとしてもよい。

【００３１】また、上記実施形態において、主光源１１から出射された光束ＬＭと副光源１２から出射された光束ＬＳとの重ね合わせ方については、これら光束ＬＭとＬＳとが同一の光路に導かれるのであれば、如何なる方法を採用してもよい。なお、上記実施形態において、制御部５９または演算処理部１１０は、低コヒーレンス干渉測定装置１０に内蔵されていなくてもよい。例えば、演算処理部１１０に代えて、外部のコンピュータに同じ処理を行わせてもよい。

【００３２】また、以上説明した本発明は、高い精度が要求される面精度測定において、特定種類の光学素子の間隔を測定する場合に、好適である。以下、本発明の他の実施形態として、上記低コヒーレンス干渉測定装置１０が面精度測定に適用された場合について説明する。

【００３３】図4は、他の実施形態を説明する図である。先ず、面精度測定には、面精度測定装置４０が使用される。面精度測定装置４０は、低コヒーレンス干渉測定装置１０と同様、光の干渉を利用した装置であるが、面精度を二次元的に観察するために、被検面４０ａに所定波面の光を照射すると共に、参照面４５ａにも所定波面の光を照射して、双方の面における反射光が成す干渉縞を２次元画像検出器４１０にて検出するものである。被検面４０ａの面精度は、その干渉縞のパターンを演算装置４１１において解析することによって得ることができる。

【００３４】ここで、被検面４０ａの設計形状が非球面である場合、それに対応するべく、面精度測定装置４０が被検面４０ａに照射する光の波面を、非球面形状に設定することがある。しかし、このような光は、進行してもその波面形状を変化させない球面波と異なり、進行するに従ってその波面形状を変化させるので、被検面４０ａの位置Ａと面精度測定装置４０の位置Ｂとの関係が光軸方向にわずかでもずれると、被検面４０ａに入射する光の状態が大きく変化し、測定誤差が生じてしまう。測定誤差をなくすためには、被検面４０ａと面精度測定装置４０との間隔を測定しておく必要がある。

【００３５】そこで、本実施形態では、この測定に、上記低コヒーレンス干渉測定装置１０を適用する。ただし、このとき演算装置４１１は、取得した干渉縞のパターンと、低コヒーレンス干渉測定装置１０が測定した間隔とに基づいて、被検面４０ａの面精度を求める。上述したように低コヒーレンス干渉測定装置１０によれば高精度な距離測定が可能なので、光の波長未満の精度が要求されるこの面精度測定を、確実に高精度化させることができる。

【００３６】なお、低コヒーレンス干渉測定装置１０が演算装置４１１に対して与える情報は、位置Ａと位置Ｂとの間隔を示す情報であれば、間隔を示す値$|X_A - X_B|$の他、位置Ａを示す値X_Aと位置Ｂを示す値X_Bとの組み合わせや、光強度データL_1と位置データX_1との組み合わせなど、如何なる形態の情報としてもよい。また、低コヒーレンス干渉測定装置１０の測定結果が利用されるのは、被検面４０ａと面精度測定装置４０との位置合わせの時であってもよい。

【００３７】

【発明の効果】以上説明したように、本発明によれば、従来の装置に一部変更を加えるだけで干渉特性曲線の包絡線の傾きが急峻化し、これによって高精度な低コヒーレンス干渉測定装置が実現する。

【図面の簡単な説明】

【図１】本実施形態の低コヒーレンス干渉測定装置１０を示す図である。

【図２】主光源１１、副光源１２の波長スペクトル分布を示す図である。

【図３】低コヒーレンス干渉測定装置１０の干渉特性曲線を示す図である。

【図４】本発明の他の実施形態を説明する図である。

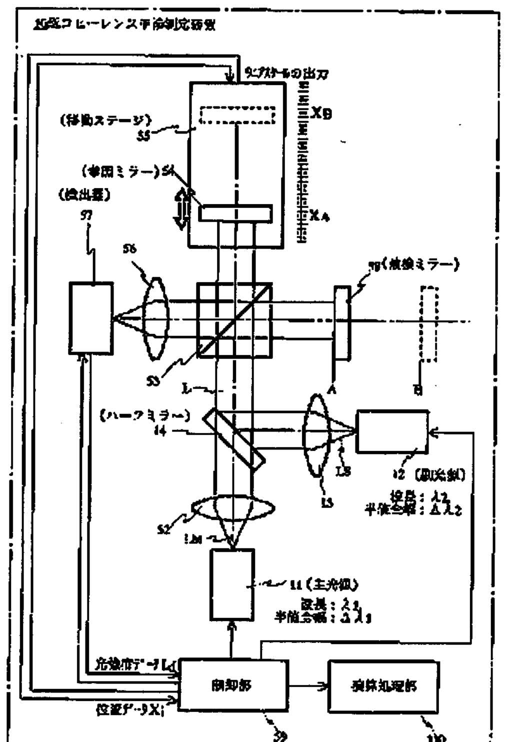
【図５】従来の低コヒーレンス干渉測定装置５０を説明する図である。

【図６】低コヒーレンス干渉測定装置５０の干渉特性曲線を示す図である。

【符号の説明】

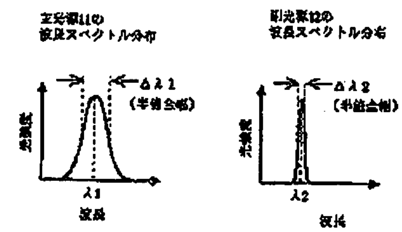
１０、５０　低コヒーレンス干渉測定装置
１１　主光源
１２　副光源
５１　光源
１３、５２、４２　コリメータレンズ
１１０、５１０　演算処理部
５３、４３　ビームスプリッタ
５８　被検ミラー
５４　参照ミラー
５５　移動ステージ
５６　集光レンズ
５７　検出器
５９　制御部
４０　面精度測定装置
４１　レーザ光源
４９　ビーム系変換光学系
４１０　２次元画像検出器
４１１　演算装置
４５　波面変換手段

【図１】



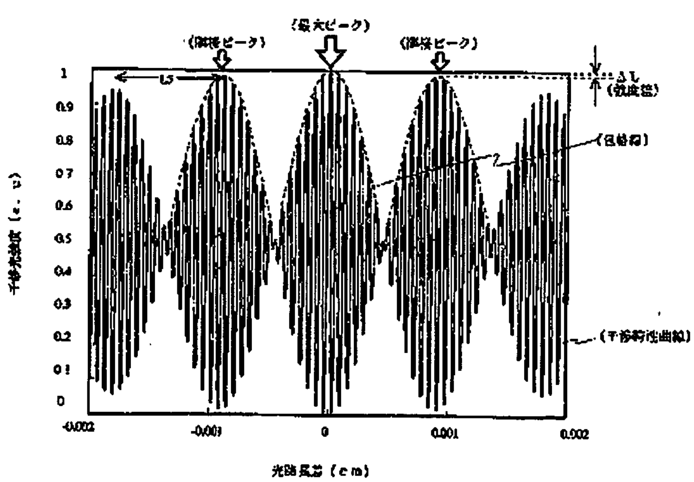
(移動ステージ)
55
54
XB
XA
(検出器)
57
56
53
L
A
B
(ハーフミラー)
14
13
52
11 (主光源)
波長：λ1
半値全幅：Δλ1
波長：λ2
半値全幅：Δλ2
制御部
演算処理部
位置データXi
59
110

【図２】



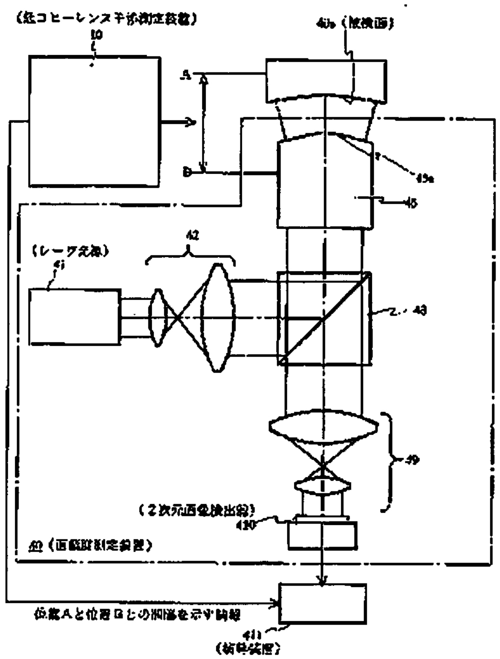
Δλ1
Δλ2
λ1
λ2

【図３】

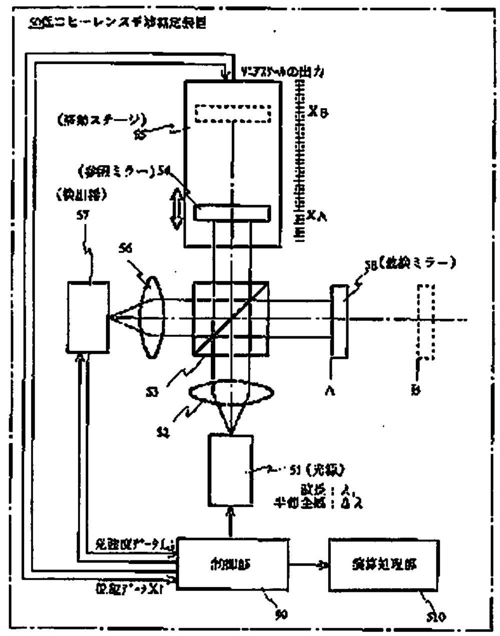


(最大ピーク)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.002
-0.001
0
0.001
0.002
光路差 (cm)

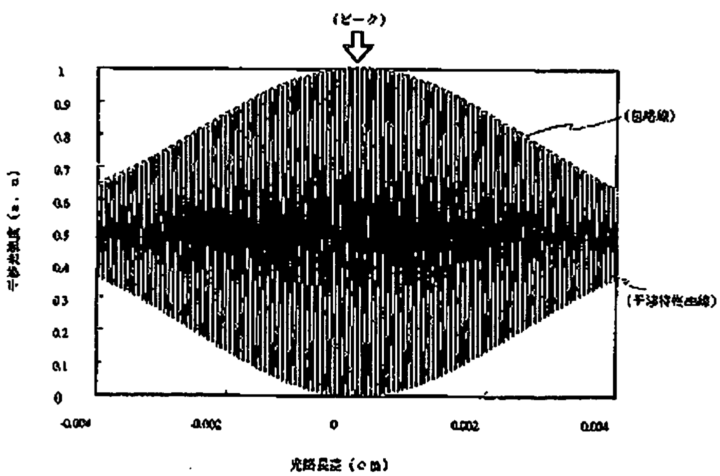
【図4】



【図5】



【図6】



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